100 Katrinas:
The Fate of America if We Keep Ignoring Art

Rosenfeld Effect
April 28, 2006

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CLIMATE BOTTOM LINE

- Most warming goes into oceans & poles
- Super-hurricanes are now the norm
- 10 more years inaction = Greenland goes (7m)
- 20 years = Serious Antarctic ice loss (20+m)
- Sea level rise 0.2 - 0.5m per decade possible
- IPCC ignores/underestimates most feedbacks
- Deploying technology now is only hope: R.E.

Earth's Energy Imbalance: Confirmation and Implications

James Hansen, et al (*Science* 2005)

Significance of Hansen's *Science* Paper:

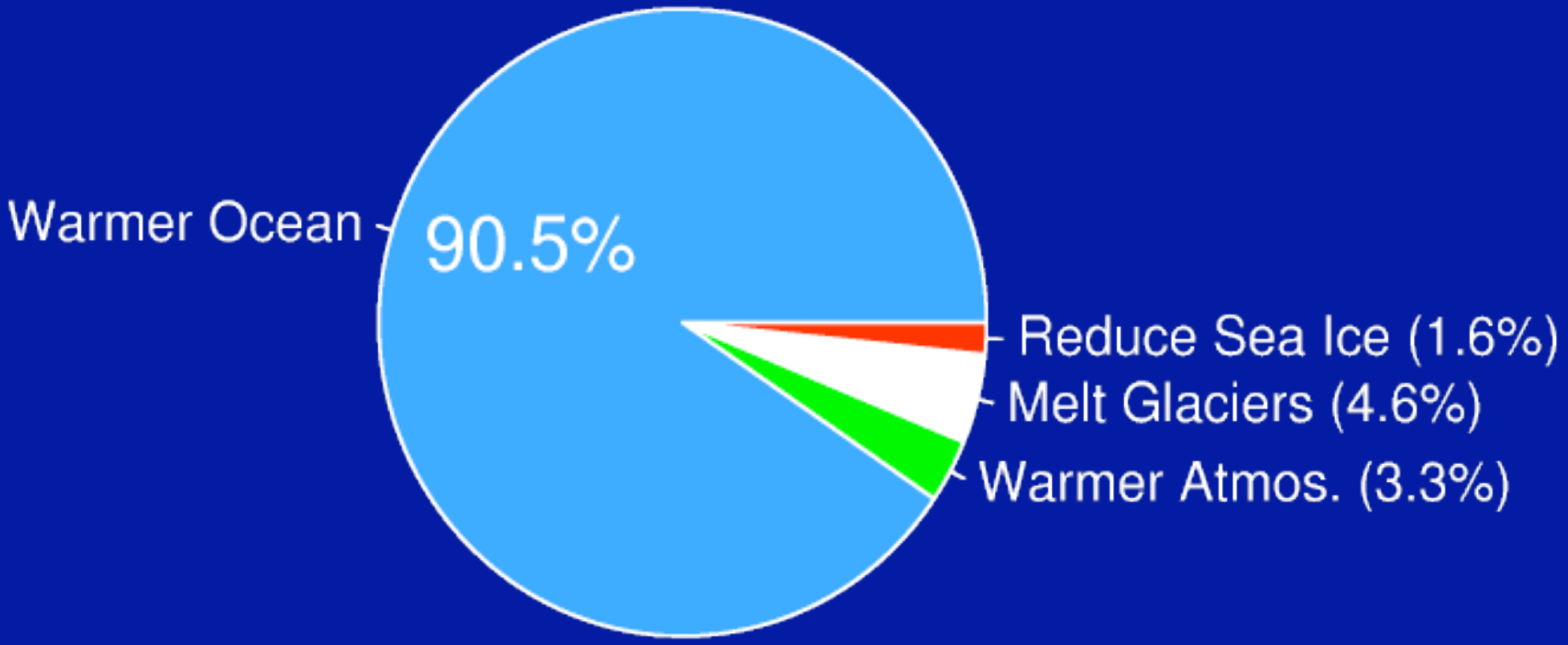
The Earth is now absorbing 0.85 +/- 0.15 W/m^2 more energy from the Sun than it is re-emitting back into space. This imbalance is confirmed by precise measurements of increasing ocean heat content over the past 10 years.

Major implications:

> ***"An expectation of additional global warming of about 0.6^{o}C without further change of atmospheric composition."***

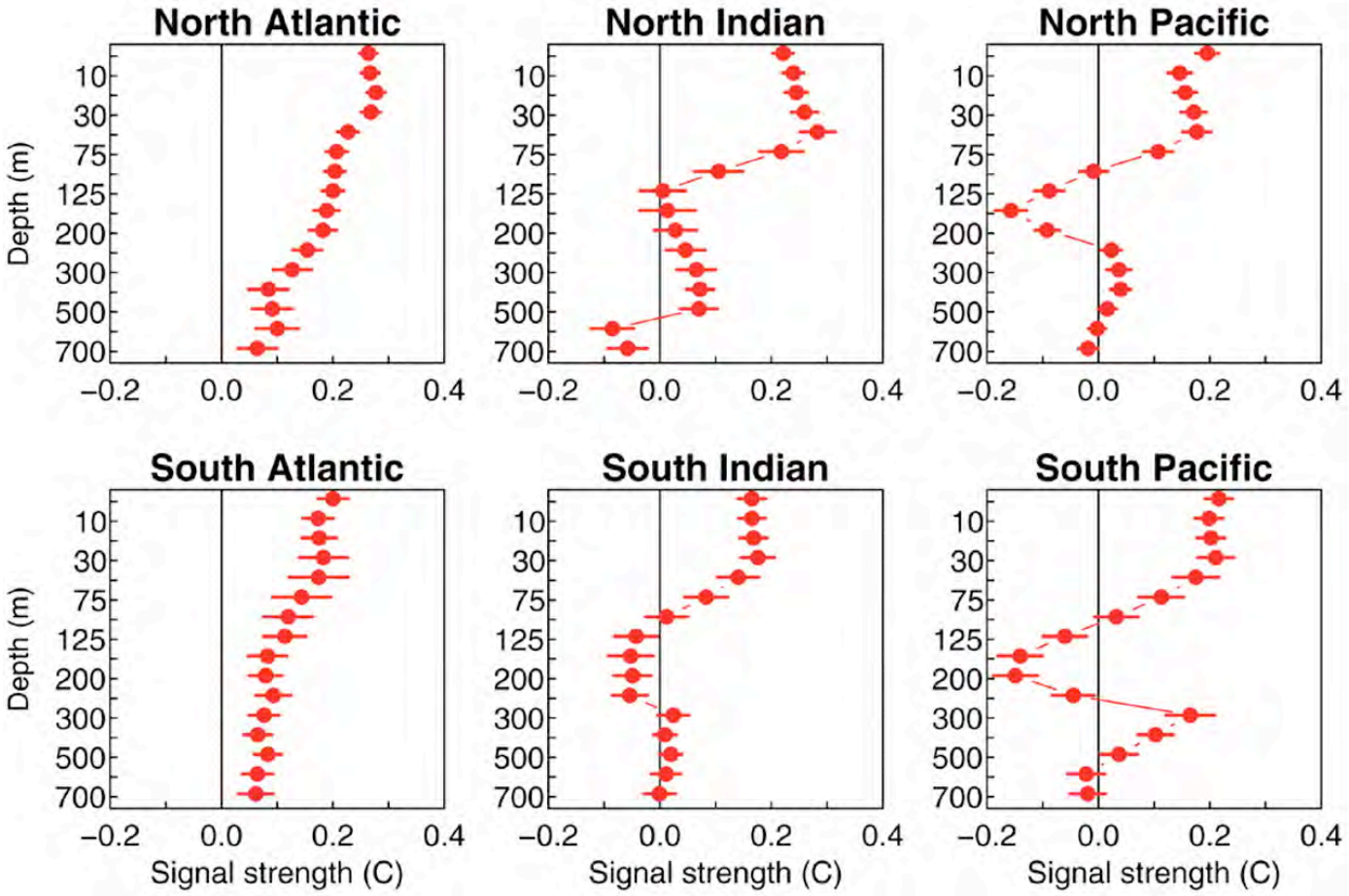
Why are the oceans Important?

Because, that is where the heat goes !



Data from Levitus et al, *Science*, 2001

Fig. 1. Warming signal strength by ocean and depth



T. P. Barnett et al., Science 309, 284 -287 (2005)

Published by AAAS

HURRICANE KATRINA

Scientists' Fears Come True as Hurricane Floods New Orleans

There are times when scientists would prefer to be wrong. Such was the case last week as Ivor van Heerden and other researchers reflected upon the devastation that Hurricane Katrina wrought on New Orleans and the Gulf Coast towns to the east. As director of Louisiana State University's Center for Public Health Impacts of Hurricanes, Van Heerden has since 2002 led a multidisciplinary team looking at what would happen if a major hurricane directly hit New Orleans. The center has studied everything from how the city would flood to how many people might ignore evacuation orders or be unable to flee—almost 1 in 4, they had estimated. "The sad part is that we called this 100%," says Van Heerden.

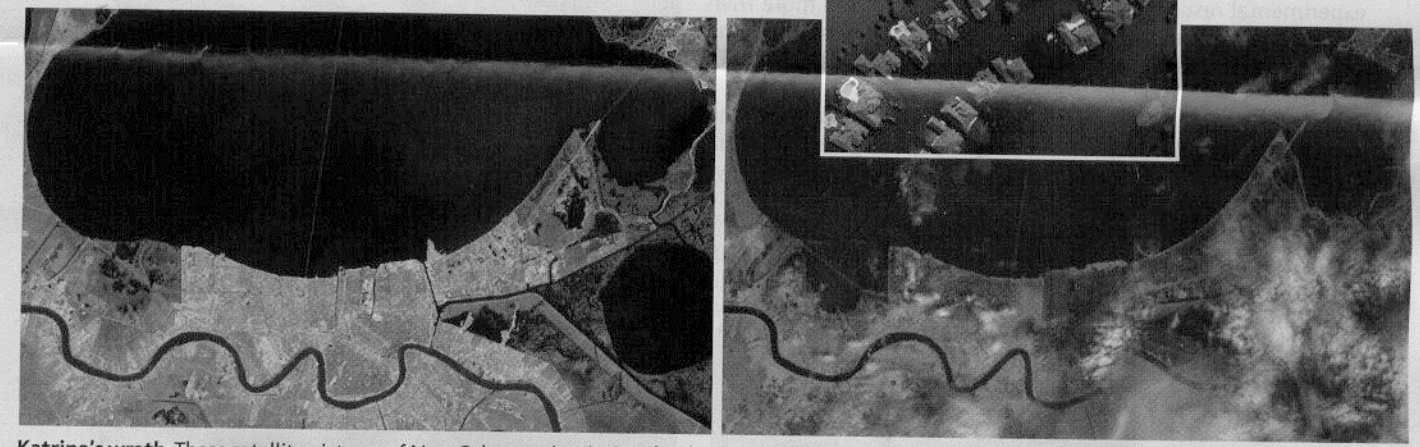
act upon them," says Rick Leuttich of the University of North Carolina, Chapel Hill, who has helped model how a hurricane could flood New Orleans. "We've had plenty of knowledge to know this was a disaster waiting to happen."

In one sense, Katrina, which left many researchers without homes and laboratories (see sidebar, p. 1657), was a rarity: Few hurricanes that powerful have struck the Gulf Coast in recorded history. At the same time, say hurricane experts, the storm contained few surprises. After speeding across south Florida as a category 1

Gulf of Mexico–Caribbean region." Two factors, says Olander's colleague James Kossin, fueled Katrina's growth: "phenomenally warm" waters in the gulf and a lack of strong, high-altitude winds that could have dispersed the storm's energy.

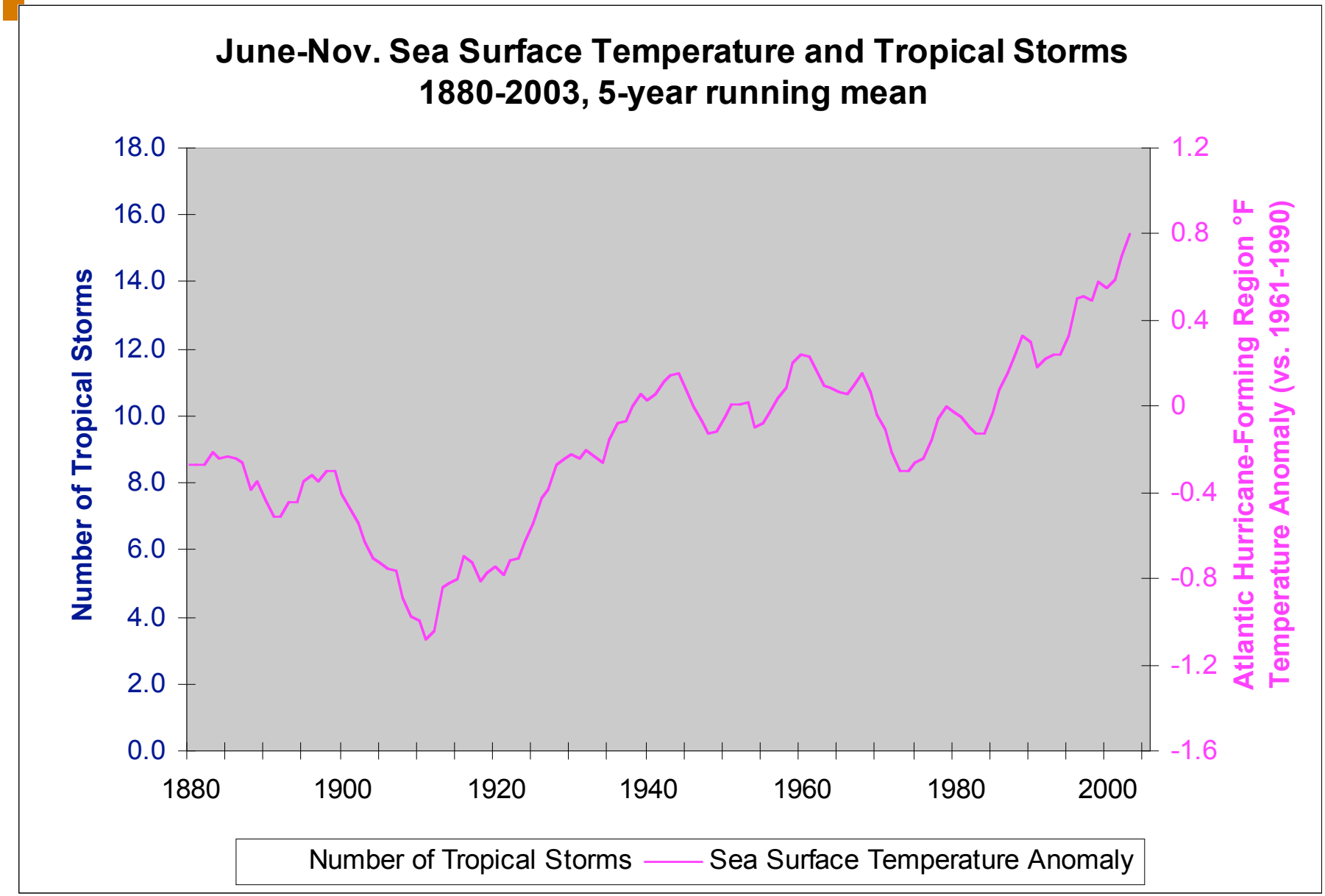
On Sunday morning, 28 August, thousands in New Orleans failed to pay heed to an evacuation order or couldn't leave. Although that shocked many, Van Heerden's center had recently polled 1000 randomly chosen New Orleans residents, using social workers to reach poor people, and had found that 21.4% would stay despite an order to leave, many of them because they lacked the means to escape.

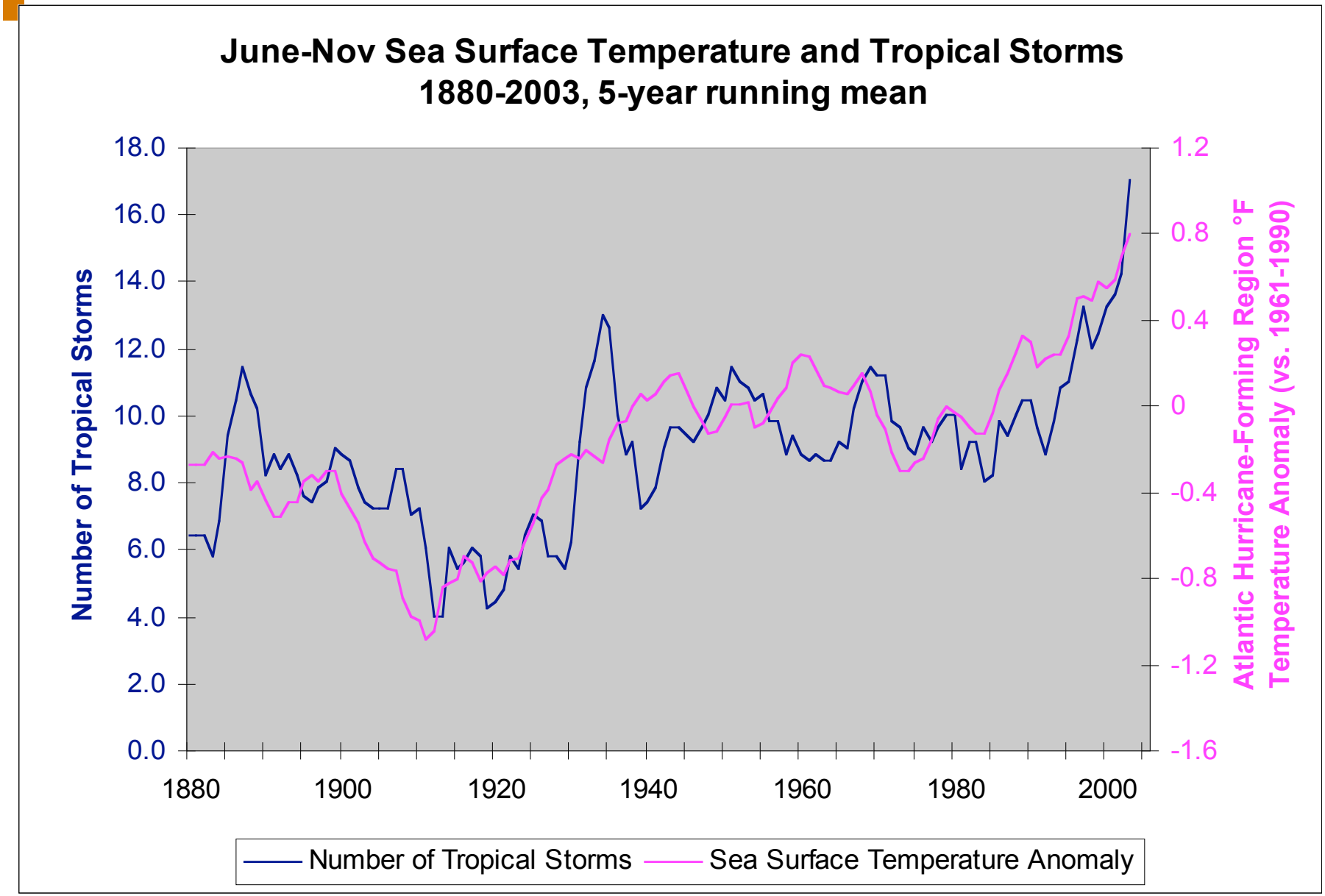
Just before landfall, Katrina took a jog to the east, sparing New Orleans from the full force of



Katrina's wrath. These satellite pictures of New Orleans taken before (*left*) and after (*right and inset*) Hurricane Katrina give a sense of the flooding caused by breaks in the levees holding back Lake Pontchartrain in the north and the Mississippi River.

NOAA


June-Nov. Sea Surface Temperature and Tropical Storms
1880-2003, 5-year running mean
Number of Tropical Storms
18.0
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0.0
1880
1900
1920
1940
1960
1980
2000
1.2
0.8
0.4
0
-0.4
-0.8
-1.2
-1.6
Atlantic Hurricane-Forming Region °F
Temperature Anomaly (vs. 1961-1990)
Number of Tropical Storms
Sea Surface Temperature Anomaly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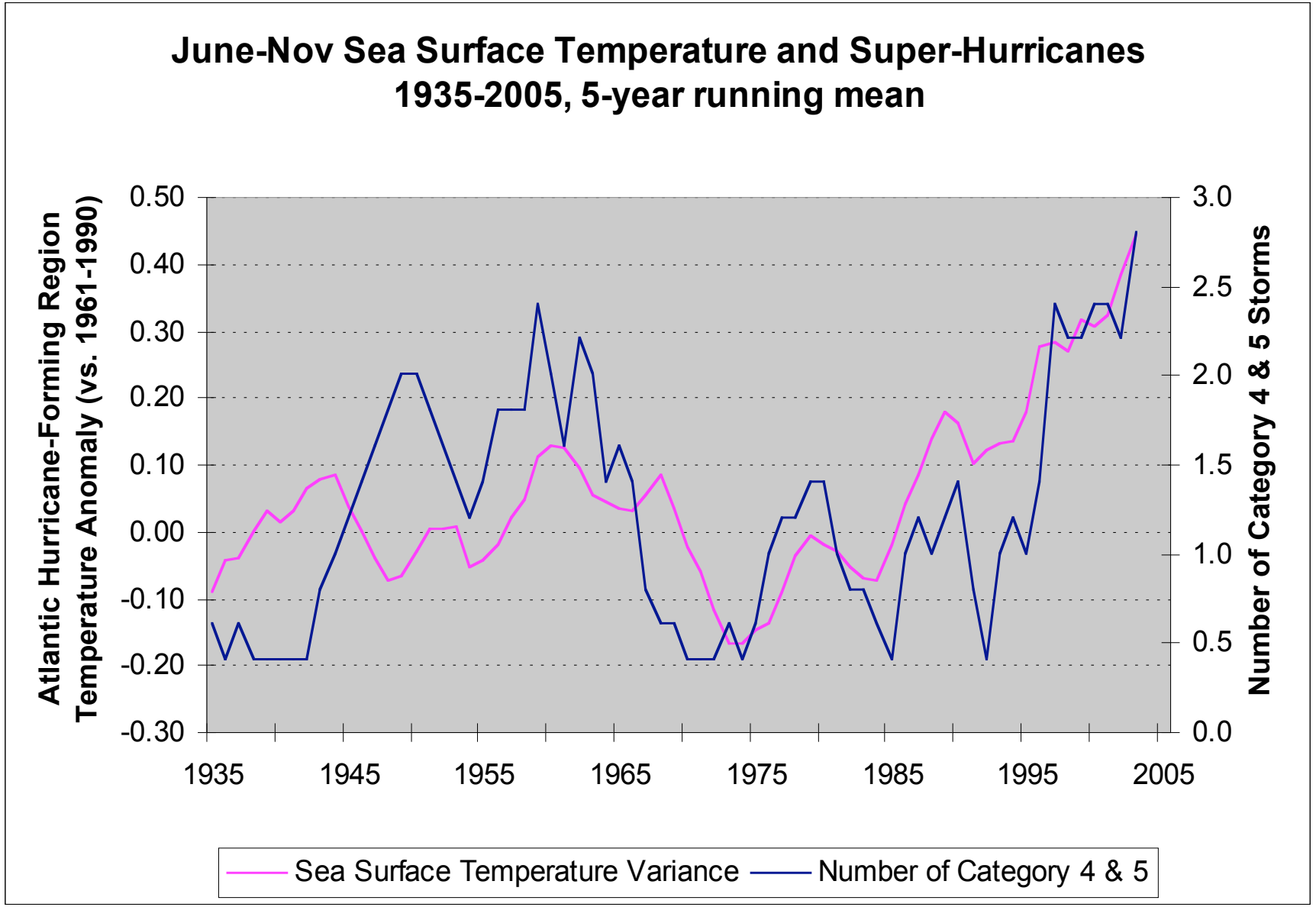
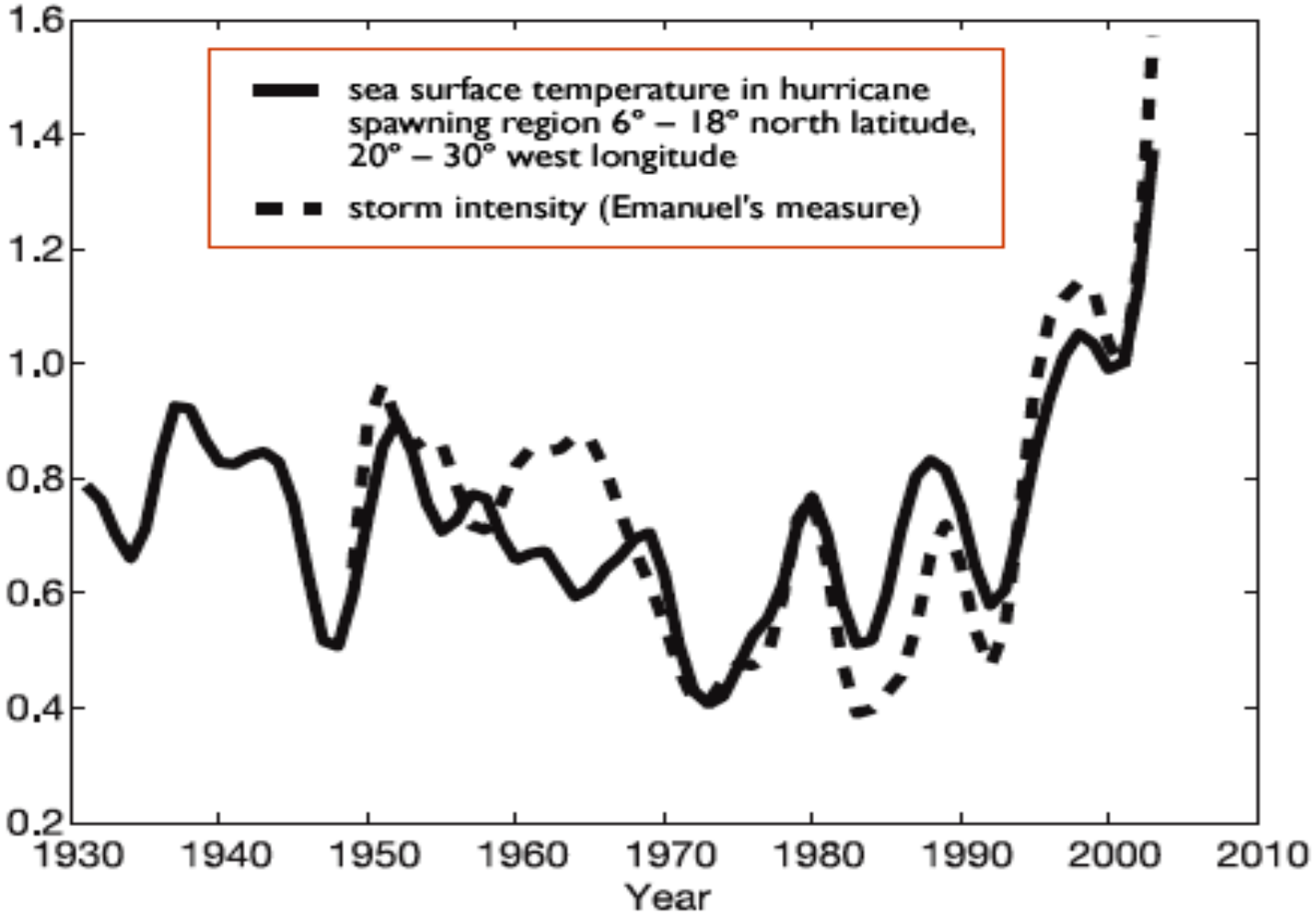

June-Nov Sea Surface Temperature and Super-Hurricanes
1935-2005, 5-year running mean
Atlantic Hurricane-Forming Region
Temperature Anomaly (vs. 1961-1990)
0.50
0.40
0.30
0.20
0.10
0.00
-0.10
-0.20
-0.30
3.0
2.5
2.0
1.5
1.0
0.5
0.0
Number of Category 4 & 5 Storms
1935
1945
1955
1965
1975
1985
1995
2005
Sea Surface Temperature Variance
Number of Category 4 & 5

Hurricane intensity vs. ocean temperature

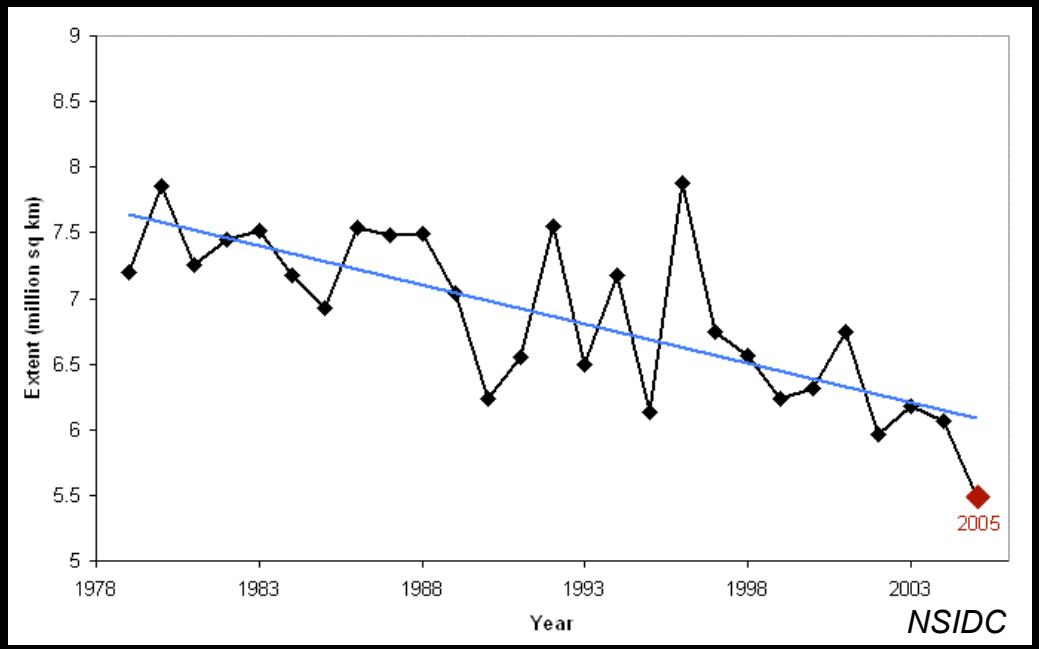


Misinforming the Public

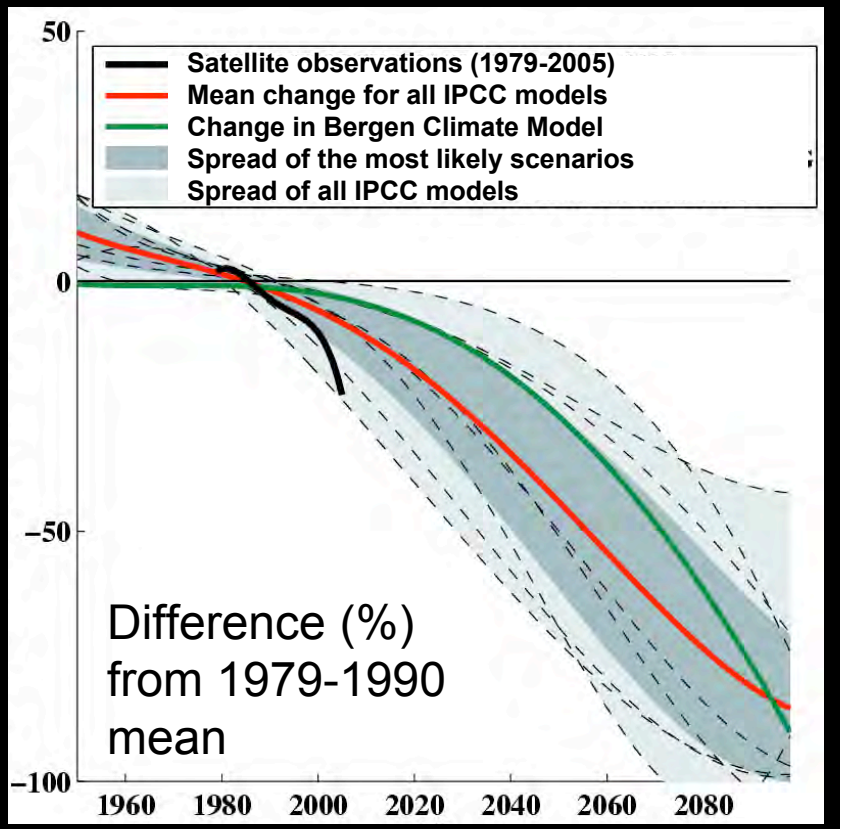
- "Well, we think the best correlation we have here [with hurricane activity] is with the sea surface temperatures." – NHC's Max Mayfield (9/05)
- "The increased activity since 1995 is due to natural fluctuations/cycles …and not enhanced substantially by global warming." – NHC's Mayfield
- "We have no direct link between the number of storms and intensity versus global temperature rise." – NOAA's Lautenbacher, post-Katrina

Observed and future sea-ice changes

Sea-ice extent September 1978-2005



Simulated Sea-ice extent



The recent sea-ice retreat is larger than in any of the (19) IPCC models

Asgeir Sorteberg
Bjerknes Centre

Likely due to unresolved feedback processes

The Greenland Ice Sheet

1) Melt area has increased 20% from 1979 to 2005.

2) Unmodeled ice loss process

3) Between 500 and 700 ppm, ice sheet disintegration likely becomes irreversible

Source: Business Week Aug. 2004

100 Katrinas

- Expect 4 to 5 super-hurricanes each year
- Expect at least one making landfall each year
- Expect 0.5-1 m sea rise by 2050, 2 m by 2100
- *Protecting* coastal cities from flooding is hard
- *Rebuilding* major coastal cities destroyed by super-hurricanes will be impossible

The Feedbacks in a Warming World

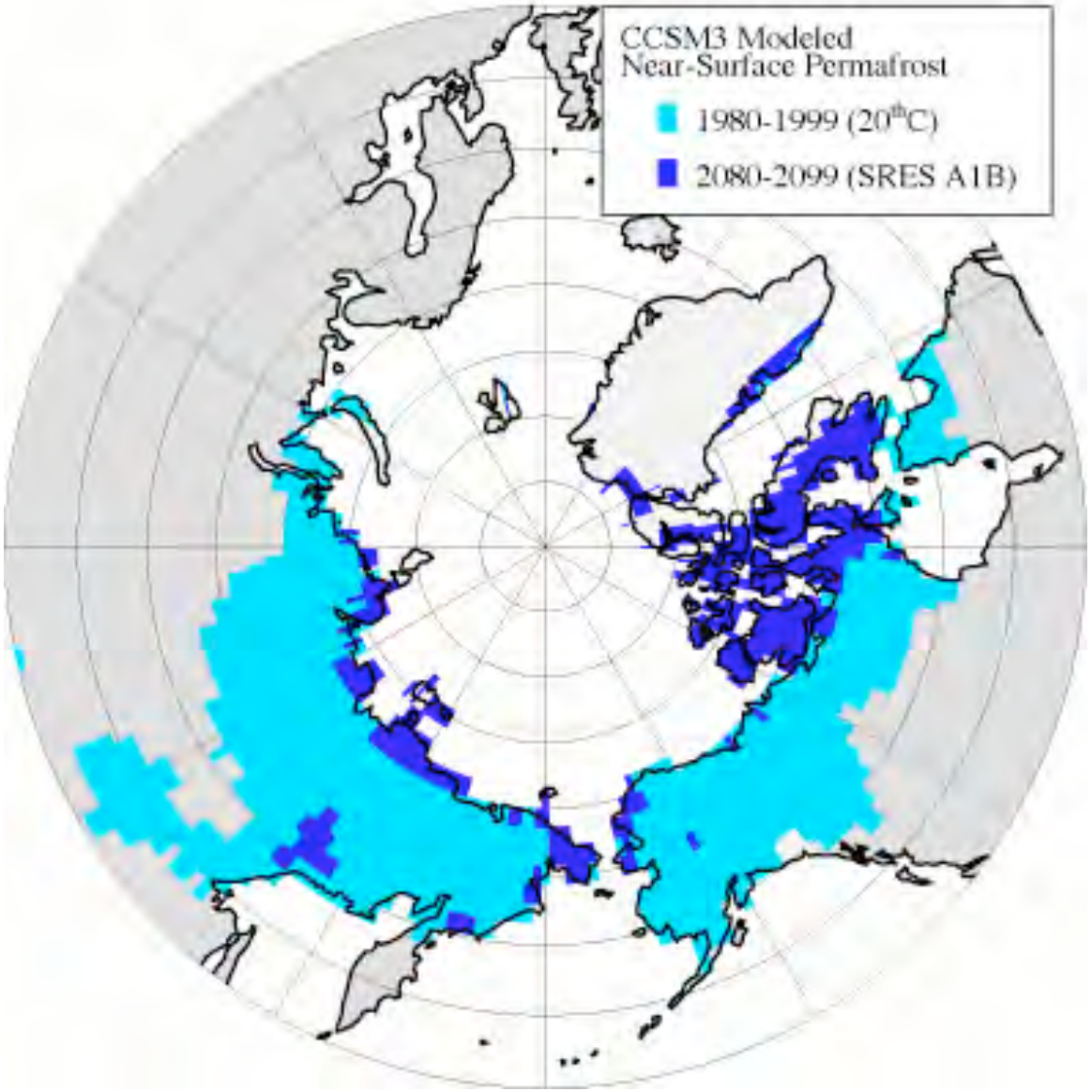
1) Oceans: stratify, acidify, and saturate.
2) Soils: T up, C content drops, turn to sinks
3) Tropical Forests: Cut down, dry out, burn up
4) Tundra C ≈ Atmospheric C

- Largely unmodeled by IPCC, these feedbacks likely kick in between 450 and 650 ppm
  - Tundra loss ~60% at 550 ppm (NCAR-05)

This sinkhole near Fairbanks, Alaska, formed due to the melting of a large ice pocket within permafrost that is gradually thawing as temperatures warm. (Photo, U. of Alaska.)

Drunken Forests

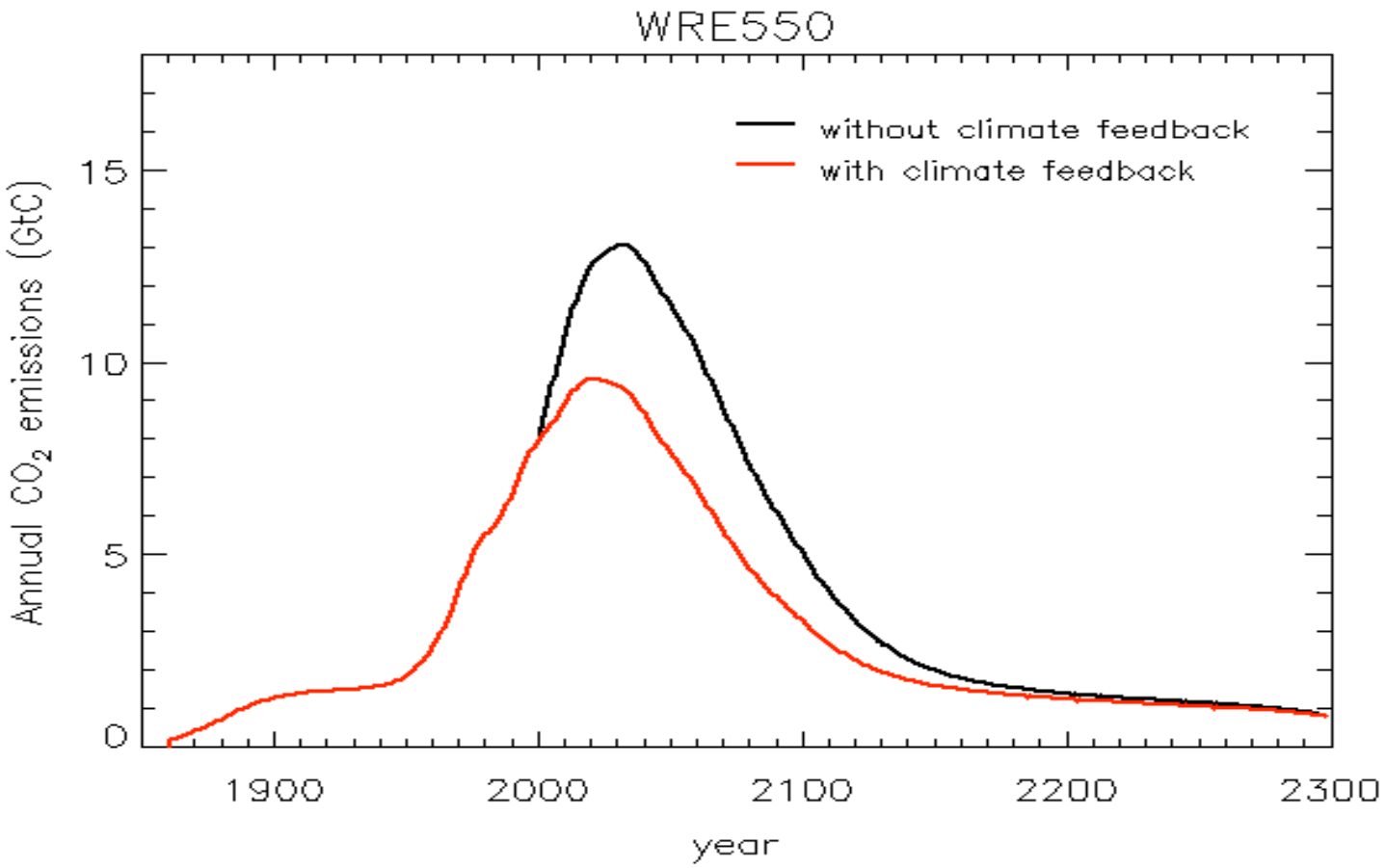
Anchorage Daily News



At 690 ppm CO2, 90% (light blue) of top 11 feet of permafrost melts by 2090s.

(Lawrence, NCAR.)

UK Hadley Center Model 2006



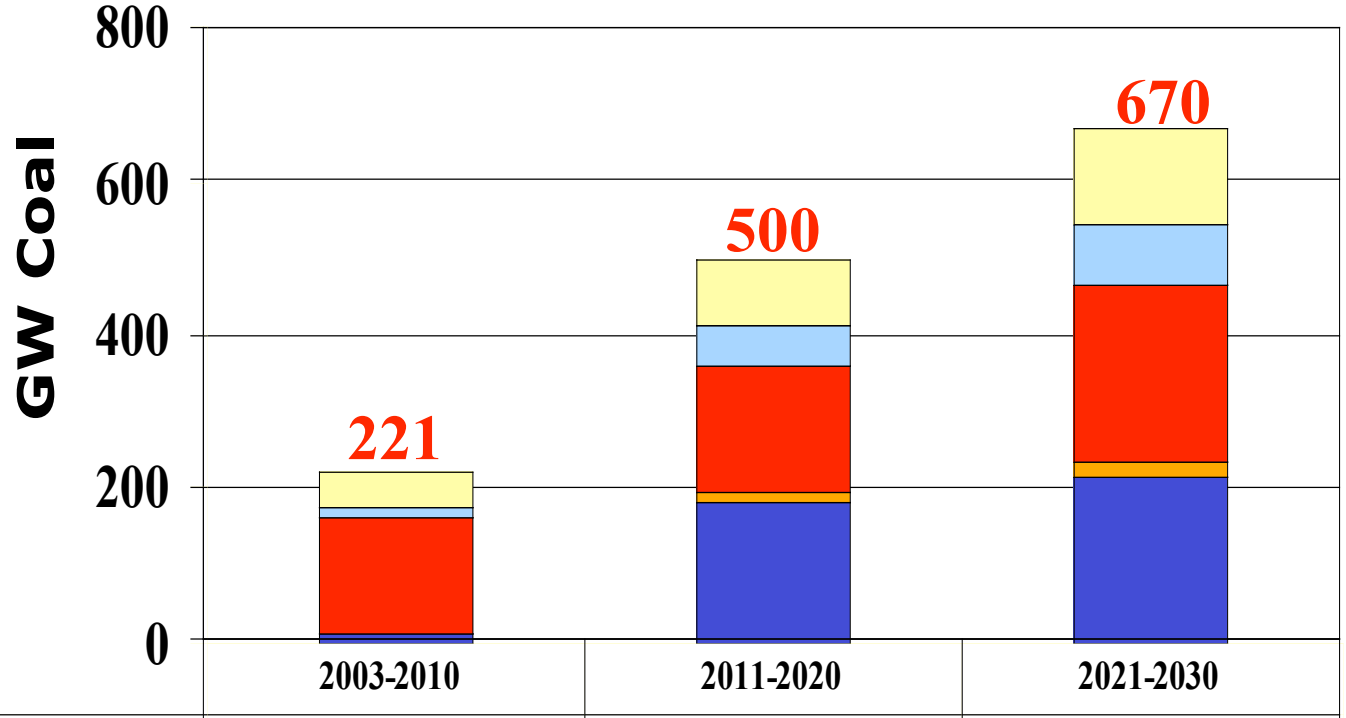
TIME FOR DELAY HAS RUN OUT

- We're at 380 ppm CO2, rising 2+ ppm/yr
- If 500 & rising in 2050, plan on 700+ in 2100
- Global emissions *must* peak ~2025
- We *must* cut CO2 emissions >50% by 2050.
- We *must* stop building traditional coal plants
- We *must* have average new car *80 mpg* in 2050

Dealing with Coal *and* Cars

- Coal strategy
  - Minimize new coal builds with efficiency
  - Replace coal with renewables, CO2 capture, etc.
  - Coal-biomass blending for gasification
- Car strategy
  - Fuel efficiency for 20+ years
  - Then need low-CO2 fuel that won't undermine efforts to deal with coal
  - Best alt fuels minimize new infrastructure

New Coal Build by Decade



	2003-2010	2011-2020	2021-2030
Other Developing	43	90	128
India	16	48	79
China	150	168	226
Transition	1	11	19
OECD	12	184	218

>$1 trillion in misallocated capital

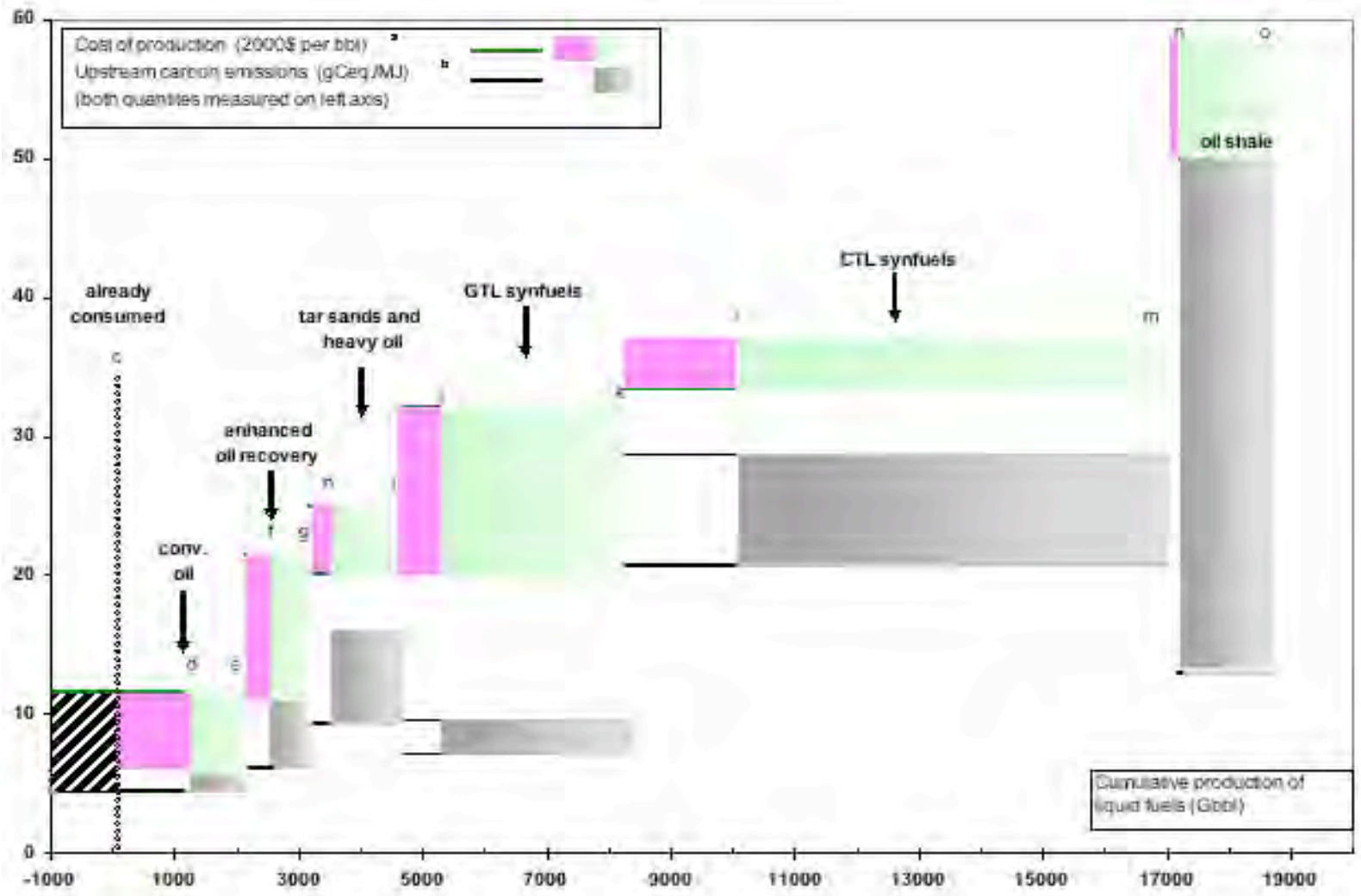
Source: IEA, WEO 2004

NRDC
The Earth's Best Defense

Unconventional Oil is Climate Disaster

- Tar Sands: Use CH4 to make C-intensive fuel
- Coal-to-Oil: Double the CO2 emissions
  - Still a bad idea with carbon capture
- Enhanced Oil Recovery diverts captured CO2
  - Should NOT be valued as geologic storage
- Shale: 1.2 GW for 100,000 barrels a day

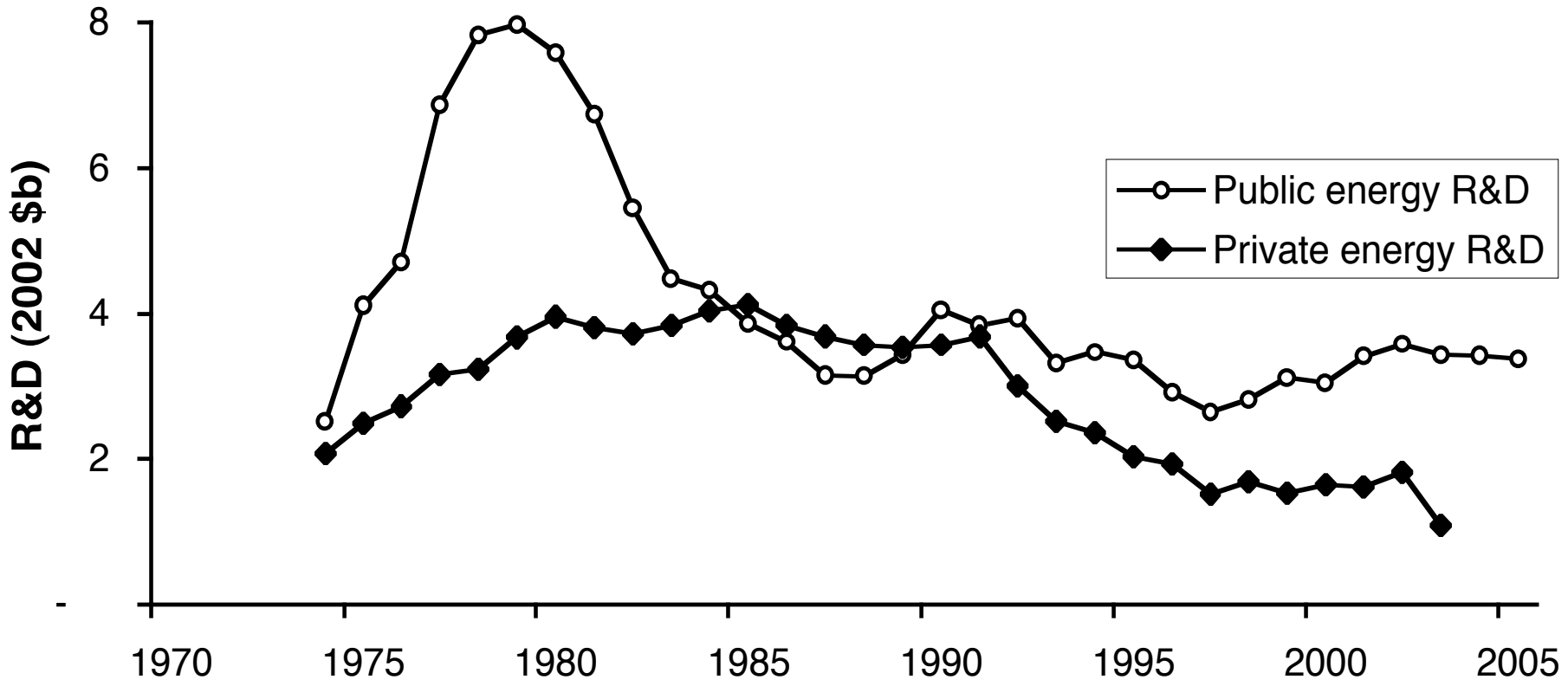
Scraping the Barrel: Brandt and Farrell



Energy Policy Priorities (in order)

1) Price for C (CO_2) > \$55 (\$15) per ton
   - Needed start price doubles ever decade we delay
2) Tough tailpipe standards for CO_2
3) Low-carbon technology deployment
4) Technology demonstration
5) Technology development
6) Basic research

If you think U.S. public sector energy R&D funding is doing poorly …

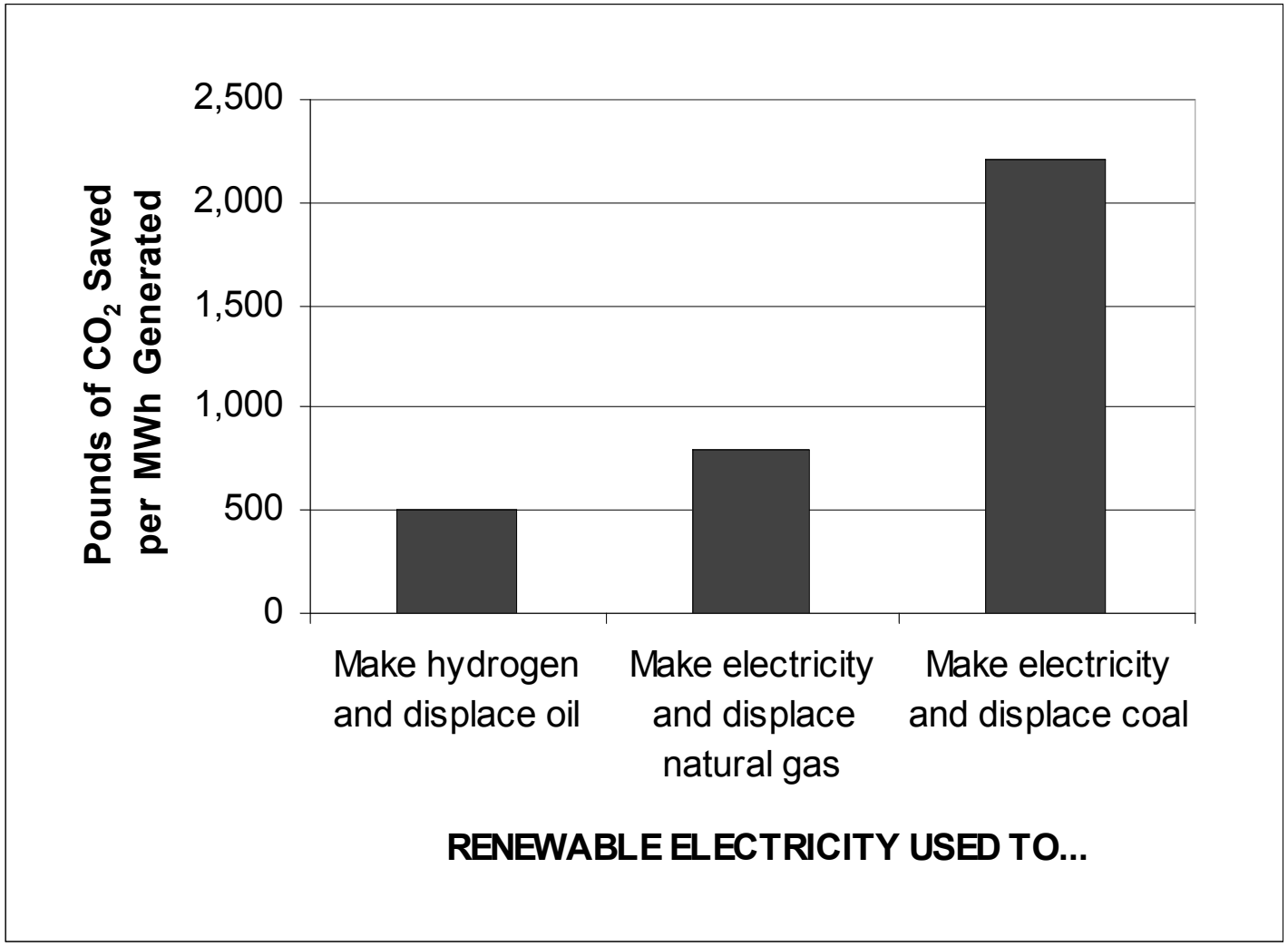


Kammen & Nemet (2005)

The Hype About Hydrogen

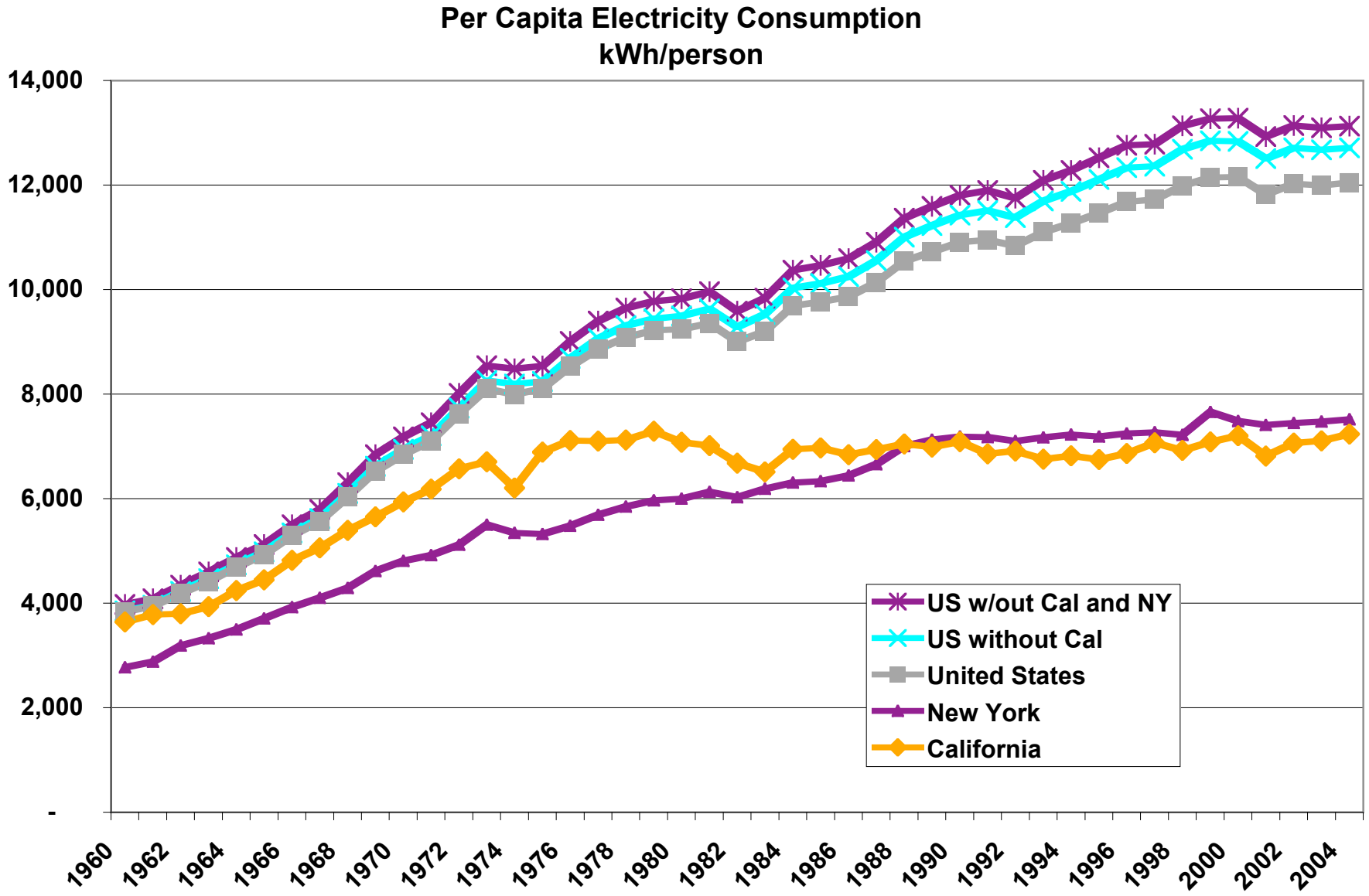
- "Total time to noticeable impact … is likely to be more than 50 years." —Heywood, MIT, 7/05
- "If I told you '**never**,' would you be upset?"

  Toyota's Bill Reinert on when H2 replaces gas, 1/05
- "Forget hydrogen, forget hydrogen, forget hydrogen." — James Woolsey, 1/06
- After "CO2 emissions from electricity generation are virtually eliminated…." — *Science*, 7/03


Pounds of CO_2 Saved per MWh Generated
2,500
2,000
1,500
1,000
500
0
Make hydrogen and displace oil
Make electricity and displace natural gas
Make electricity and displace coal
RENEWABLE ELECTRICITY USED TO...

Car of the Future: Plug in Hybrids

- 20-mile electric range, then reverts to hybrid
- Could displace half of gasoline
- Works best with carbon cap
- Blend in cellulosic ethanol
- Why use future clean electricity for H2?
  - Plug in uses electricity *3 to 4 times more efficiently*
  - Make use of existing infrastructure/vehicles


Per Capita Electricity Consumption
kWh/person
14,000
12,000
10,000
8,000
6,000
4,000
2,000
-
1960
1962
1964
1966
1968
1970
1972
1974
1976
1978
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
2004
US w/out Cal and NY
US without Cal
United States
New York
California

The Anti-Technology Administration I

- "[Secretary] Abraham said no technologies currently exist to significantly cut emissions of gases linked to global warming." DOE PR 9/03
- "Are we going to tell people to stop driving their cars, or do we start investing in technology [to cut emissions]? That's the answer, investing in those technologies."

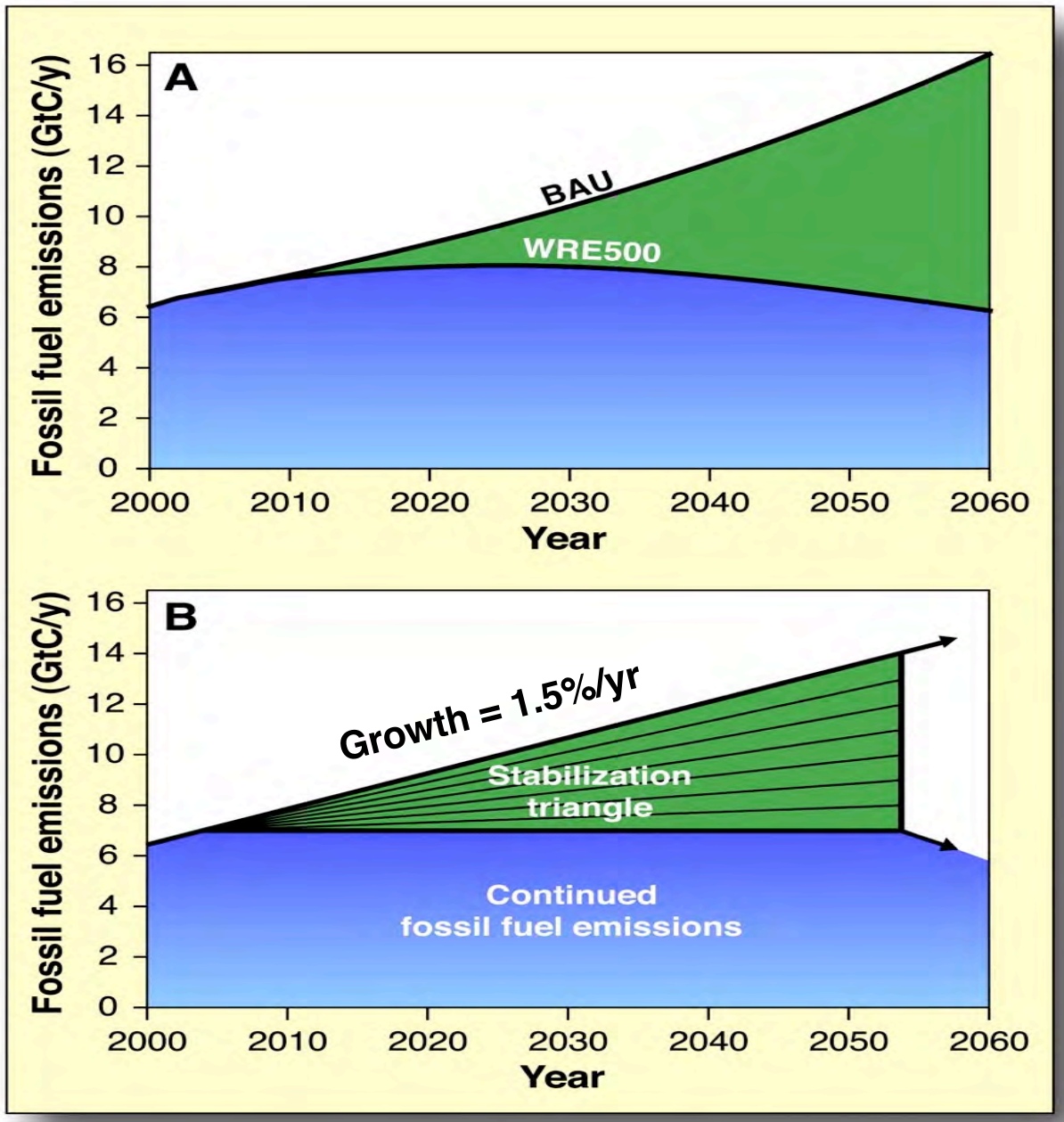
  — EPA Administrator Stephen Johnson, 1/06

The Anti-Technology Administration II

- Regional offices to be shut down
- Industrial efficiency to be zeroed out
- Efficiency: $1.18B (FY07) to $1.13B (FY11)
- HFCV: $196M goes to $323M
- Bodman disbands science & tech advisors
- “The secretary has an understanding of science and scientific processes.” — DOE 4/06

The Breakthrough Reality

- What technology breakthroughs in the past three decades have transformed how we use energy today?
- There haven't been any.
- "Typically it has taken 25 years after *commercial* introduction for a primary energy form to obtain a 1% share of the global market." — Royal Dutch/Shell 2001

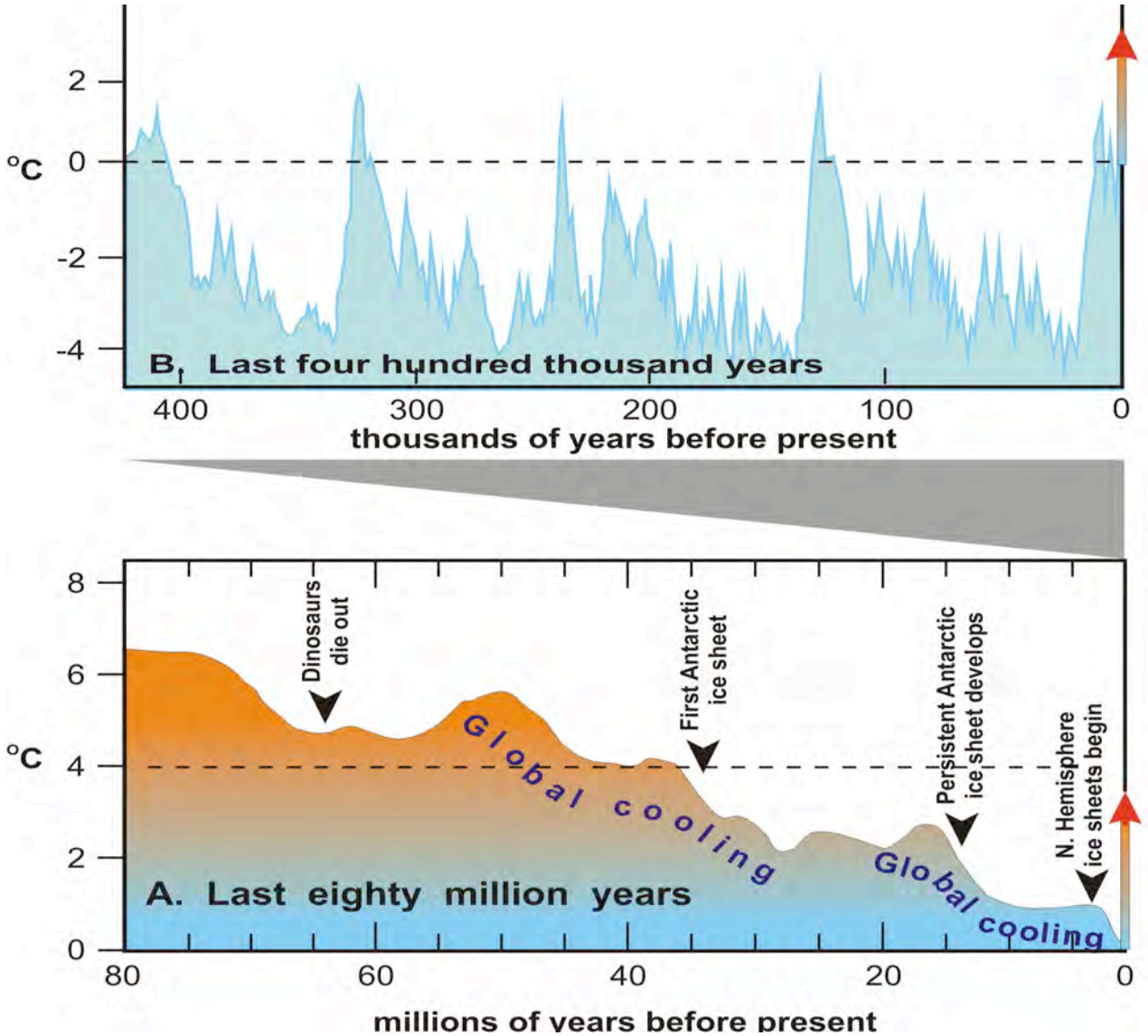


Source: Stabilization Wedges: Pacala and Socolow, Science Vol 305, page 968

Avoiding Climate Catastrophe
WEDGES: 2010 to 2060

- California-style program for building efficiency
- Similar program for industry efficiency plus cogen
- Carbon capture & storage for 800 GW coal
- Build 2000 GW of wind turbines (or equivalent)
- Build 700 GW new nuclear plants.
- All cars 60 miles per gallon.
- All cars flex fuel plug-ins (+ 1000 GW more wind and one-twelfth of world's cropland for biofuels).
- End all tropical deforestation. Double tree planting.

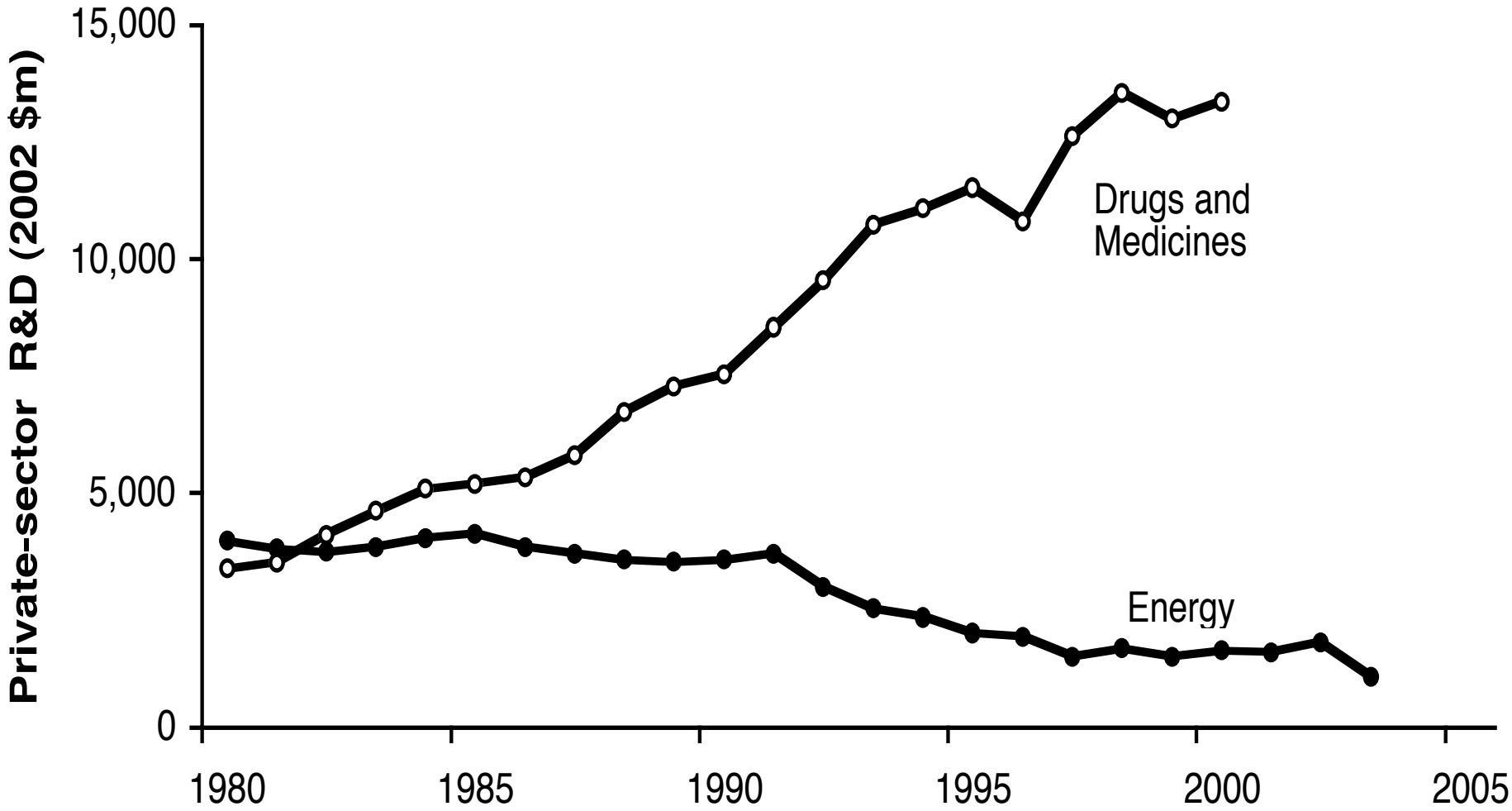
What 2, 3, 4 Degrees Warming Means



The Future History Of Science

- “It may seem impossible to imagine that a technologically advanced society could choose, in essence, to destroy itself, but that is what we are now in the process of doing.” (Kolbert, 2006)
- When future historians write with justifiable bitterness about our time, they will certainly judge the Bush Administration very, very harshly, but I’m not so certain the rest of us are going to fare that well either.

Private Sector R&D Investment in Health and Energy



Kammen and Nemet, 2005